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Enhancement of vein patterns in hand image for biometric and biomedical application using various image enhancement techniques

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Abstract

Captured hand image needs better enhancement technique to detect the vein patterns, due to existence of indistinct state and unwanted noise in hand image which result in false detection of veins. The image preprocessing such as image enhancement techniques are necessary to improve the image for visual perception of humans and making further easy processing steps on the resultant images by machines. This paper explains various enhancement techniques such as image negative, gray level slicing, histogram equalization, contrast stretching, laplacian sharpening, unsharp masking, high boost filtering, and histogram equalization of high boost filter. These techniques are applied on the hand image using (OpenCV) open source computer vision library developed by Intel. A comparative study of all these enhancement techniques is carried out to find the best technique to enhance hand vein pattern. The result shows the histogram equalization of high boost filtering technique provides better enhancement of vein pattern. Image quality measures (IQMs) are figures of merit used for the evaluation of imaging systems are also evaluated.

Keywords: Image Enhancement; Hand Vein Application; Histogram Equalization; High Boost Filtering, Image Quality Measure

1. INTRODUCTION

In human circulatory system, veins are the blood vessels that carry deoxygenated blood (poor in oxygen) from the tissues back to the heart. Veins are available close to the surface of the skin as well as

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away from it, the closer ones are called superficial veins and other ones away from the skin are called deep veins. Even though superficial veins are closer to the skin they are not completely visible for naked eyes only a part of it is visible [1]. By making the vein pattern visible or detecting, it could be applied to the fields of biometrics and biomedical. For both the application, the vein detection is considered on the upper limb superficial vein especially on the back of the hand above the wrist region [2] [3]. To detect the vein on the specified part, certain acquisition steps of hand image is required.

Nomenclature

$i(x, y)$	input image	p_{in}	input pixel value
$i_{neg}(x, y)$	singed negative image	b, a	desired minimum and maximum value
$i_{negu}(x, y)$	unsigned negative image	c, d	minimum and maximum value in the original image.
$p(r_k)$	Probability of gray value r_k	$G(x, y)$	Gaussian function in 2-D
n_k	Number of pixel with gray level	σ	standard deviation
n	Total no of pixels in the image	$f_{original}(x, y)$	original image
$cdf(v)$	Cumulative Distribution Function of a gray value	$i_{lowpass}$	low pass image
$cdf_{\min}$	minimum CDF value in the image	$i_{highpass}$	high pass image.
$M * N$	width*height of the image	A	ranges above the value of 1
L	total gray level in the image	K	value ranges from 0.2 to 0.8
$h(v)$	histogram equalization value	$\nabla^2 f(x, y)$	second order derivative image
p_{norm}	normalized image	$l(x, y)$	Laplacian image
		$f_{unsharp}(x, y)$	unsharp image
		$f_{highboost}(x, y)$	high boost filtered image

In recent years, hand vein pattern biometrics has attracted increasing interest from both research communities and industries [4]. In biometrics, veins are unique patterns for every individual and can be used for accessing, identifying, authenticating purposes. From the detected vein, certain features are extracted out and matched with already stored features by using classifier for the above mentioned purposes. In biomedical, catheterizations on vein are performed by trained professionals, even they also find difficulties in finding veins in emergency cases. So the aiding system pointing on a hand region recognizes the vein patterns in that region and projects it back on the same region makes the vein visible for catheterization purpose [5] [6]. Vein detection requires better enhancement processing stages; so, in this paper various enhancement operations are carried out on the captured hand image. Various image enhancement technique for hand vein detection that are viewed in this paper are image negative, gray level slicing, histogram equalization, contrast stretching, unsharp masking, laplacian sharpening, high boost emphasis filtering. Image quality measures are carried out on all the enhancement techniques of hand vein image and the result shows histogram equalization of high boost filter technique provide better image and also better image quality measure values.

2. METHODOLOGY

A snapshot of specified hand region is captured by CCD camera under a wavelength range of Near Infrared (700nm-1400nm) [7]. Need of Near Infrared range in the acquisition stage of hand image is required to detect the vein because the vein carrying deoxygenated blood absorbs this range while the rest of the hand like skin, hair and arteries reflects this range of illumination. Array of LED sources illuminating NIR wavelength is placed around the CCD camera in the form of concentric circle structure [8]. With this setup, captured hand image viewed on PC a structure of dark patterns are visible on the hand which are vein patterns due to absorption. This captured image hand vein image is applied for various enhancement techniques.

2.1. Enhancement technique

Operations on the image can be performed both by spatial domain as well as by frequency domain [9]. Spatial domain enhancement techniques are analysed in this paper. Enhancement operations are of point enhancement and spatial enhancement operation. Point enhancement operations are image negative, gray level slicing, histogram equalization and contrast stretching. Spatial enhancement operations are laplacian sharpening, unsharp masking, high boost filtering.

2.2. *Image negative*

Image negative is primarily contrast enhancement operation by converting input pixel one by one to modified new value [9]. It is used to enhance the gray or white detail embedded in dark region of an image. Original image pixel values are inverted using image negative operation by point operation. Image negative for signed data type source image the operation can be performed by

$$i_{neg}(x,y) = -i(x,y) \tag{1}$$

For unsigned data type source image the operation can be performed by

$$i_{negu}(x,y) = 255 - i(x,y) \tag{2}$$

2.3. Gray level slicing

Gray level slicing is a point operation enhancement technique in which the slicing of specific gray values from the rest of the gray values for enhancement [9]. The method has two approaches. In one approach a specific gray values alone enhanced to a brighter gray value and unspecified gray level are left unchanged; it can also be said as gray level slicing with background. In another approach a specific gray values are enhanced and the remaining gray values are set to zero; it can also be said as gray level slicing without background which yields a binary image.

2.4. Histogram equalization

Histogram equalization is a contrast adjustment technique which uses image histogram. Image Histogram acts as a graphical representation of the gray value distribution. It plots number of pixel for each gray value. The horizontal axis of the graph represents the gray value distribution and the vertical axis represents the no of pixel in each gray level. This technique can be implemented by getting the probability of occurrence of gray level in an image [9] and it is given by

$$p(r_k) = n_k / n \quad ; \quad k=0, 1, 2\ldots\ldots L\text{-}1 \tag{3}$$

The transformation function can be

$$s_k = T(r_k) = \sum_{j=0}^{k} p(r_k) \quad ; \quad k=0, 1, \ldots, L\text{-}1 \tag{4}$$

The above equation right side is recognized as cumulative distribution function. A plot of $p(r_k)$ versus r_k is called histogram. The transformation given above is called histogram equalization or histogram linearization. To get histogram equalized image, histogram of the image is to be obtained then the cumulative distribution function of the image is obtained. The CDF must be normalized to [0,255]. The general histogram equalization formulae is

$$h(v) = round((cdf(v) - cdf_{\min} / (M * N) - cdf_{\min}) * (L-1)) \tag{5}$$

2.5. Contrast stretching

Contrast stretching often called as normalization is a simple image enhancement technique in which image pixel's range of intensities is spanned to desired range of values. The implementation of this method is by specifying the desired minimum and maximum value limits over which the image is to be normalized. Now the histogram of the original image is to be obtained and from that the minimum and maximum value are obtained. From the function below the pixel in the original image are scaled by [10]

$$p_{norm} = (p_{in} - c)((b-a)/(d-c)) + a \tag{6}$$

2.6. Sharpening

Image sharpening has the goal of enhancing the details of the image. A high-pass filtered image can be obtained as the difference between the original image and its low-pass filtered version. The low pass filtered image is obtained by convoluting the original image with the masks $w_{lowpass}$ given below

$$w_{lowpass}(x,y) = 1/6\begin{bmatrix} 0 & 1 & 0 \\ 1 & 2 & 1 \\ 0 & 1 & 0 \end{bmatrix}, 1/9\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}, 1/16\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

$$f_{lowpass}(x,y) = f_{original}(x,y) * w_{lowpass}(x,y) \tag{7}$$

The * operator is a convolution operator and the high spatial frequency image is obtained by subtracting the low pass filtered image from the original image.

$$f_{highpass}(x, y) = f_{original}(x, y) - f_{lowpass}(x, y) \tag{8}$$

Band pass filter is also an image enhancement technique which involves the subtraction of the blurred version of the image from another less blurred version of an image. The blurred version of the image is also produced by convolving the image with Gaussian kernels having different standard deviation. The Gaussian function is provided below

$$G(x, y) = 1/\left(2\prod\sigma^2\right) * \ell^{-\left(x^2+y^2/2\sigma^2\right)} \tag{9}$$

From the above function the kernel is formed by giving the standard deviation value and substituting the position of kernel. Suppose σ =1.0. By convoluting the below kernel with the image a blurred image is produced.

$$G(x, y) = \begin{bmatrix} .058 & .095 & .058 \\ .095 & .150 & .095 \\ .058 & .095 & .058 \end{bmatrix}$$

2.7. Laplacian sharpening

Laplacian sharpening is a second order derivative method of enhancement which finds fine details in an image and it is to restore fine detail to an image. First order derivative such as Sobel, Roberts operators are used to find edges in an image. Here the derivative operator is used to sharpen the fine details of the image. The laplacian of an image highlights region of rapid intensity changes. The above equation is the second order derivative operator which can also be implemented by using the mask given below. After applying laplacian mask to the image, laplacian filtered image is obtained. The laplacian filtered image consists of positive as well as negative values i.e. from -255 to 255, so scaling has to be performed on the laplacian filtered image. Then the scaled laplacian image is subtracted from the original image to provide the laplacian sharpened image.

$$\nabla^2 f = \partial^2 f / \partial x^2 + \partial^2 f / \partial y^2 \tag{10}$$

$$\nabla^2 f = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}; \nabla^2 f = \begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

$$l(x, y) = f(x, y) - \nabla^2 f(x, y) \tag{11}$$

2.8. Unsharp masking

The unsharp filter is a simple sharpening operator that enhances edges and other frequency components in an image through a procedure which subtracts an unsharp or blurred version of an image from the original image provides high pass image [11]. This high pass image is added to the original image to provide the sharpened image by unsharp masking.

$$f_{unsharp}(x, y) = f(x, y) + k * f_{highpass}(x, y) \tag{12}$$

2.9. High boost filtering

In this case, the high-boost filter can be used to enhance high frequency component while still keeping the low frequency components [11]. A slight further generalization of unsharp masking is called high boost filtering. A high boost filtering image is defined at any point as

$$\begin{aligned} f_{highboost}(x, y) &= A * f(x, y) - f_{lowpass}(x, y) \\ &= (A-1)f(x, y) + f_{highpass}(x, y) \end{aligned} \tag{13}$$

3. Result and Discussion

To compare various the image enhancement techniques, the comparison of image before and after enhancement is provided. The various enhancement techniques are applied to two original hand images (Fig 1 (a), Fig 1 (b)). The analyses of enhancement images are based on the human interpretation. Fig 1 (a) Shows the captured hand image with veins distinct and (b) captured hand image with veins indistinct. Fig 2, Fig 3, Fig 4, Fig 7, Fig 8 and Fig 9 shows the result of each enhancement technique applied to the original image.

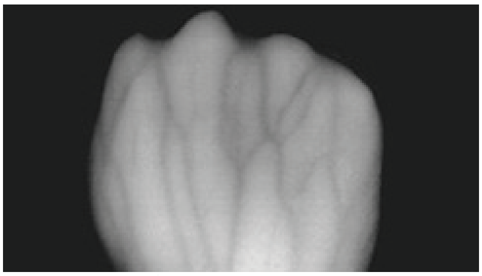

Fig 1 (a) cdaptured hand image with veins distinct; (b) captured hand image with veins indistinct

Fig 2 (a) and (b) shows the result from image negative enhancement technique for the original images. From the Fig 2 (a) and (b) it is observed that the vein pattern becomes lighter compared to the rest of the image region. In the image negative enhancement operation the high illumination effects are visible as dark patterns. Negative image enhances white or gray details embedded in dark regions of the original whereas the dark regions i.e. vein in the original image are not enhanced. Hence image negative is not suitable enhancement technique for vein detection.

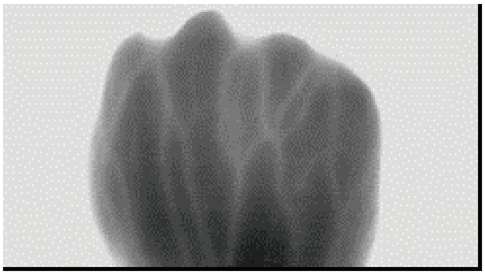
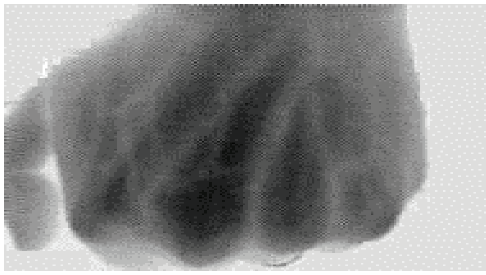

Fig 2 (a) Negative image of Fig 1 (a); 2 (b) Negative image of Fig 1 (b)

Fig 3 (a) shows the result from gray level slicing enhancement technique, slicing in the range of 150-220 gray values of fig.1 (a). The Fig 3 (b) shows the result from gray level slicing enhancement technique, slicing in the range of 100-200 gray values of Fig 1 (b). From the Fig 3 (a) and 3 (b) it is observed that veins are not clearly sliced in that range properly. It is to be pointed out that for this enhancement technique gray values of the vein patterns should be known ahead for slicing those patterns alone. The enhancing value used in both the original image is 1.5. Generally gray level slicing technique is not suitable for automation because every time the gray values have to be provided for slicing and the desired patterns vary their values due to illumination condition. Hence gray level slicing is not suitable enhancement technique for vein detection.


Fig 3 (a) Gray level sliced image (gray value range 150-200) of Fig 1 (a); 3 (b) Gray level sliced image (gray value range 100-200) of Fig 1 (b)

Fig 4 (a) and (b) shows the result from histogram equalization enhancement technique for the Fig 1 (a) and Fig 1 (b). Original image covers only narrow range of gray value in the histogram and makes it as a low contrast image. To increase the contrast of an image, gray values in the original are spread throughout the entire range of gray level value [0-255] without distortion. From the Fig 4 (a) and 4 (b) it is observed that this technique increases the contrast of the original image but it also introduce undesirable patterns and noise. The contrast stretching enhancement technique also provides the same result of histogram equalization but the latter one is used for automation. Hence this enhancement of vein patterns is not sufficient enough.

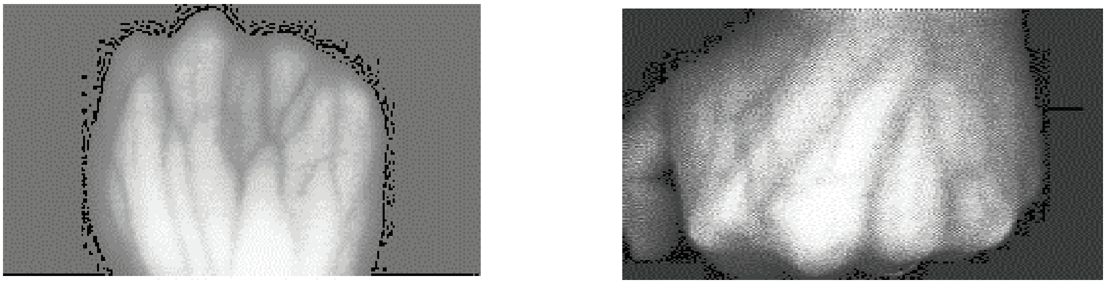

Fig 4 (a) Negative image of Fig 1 (a); 4 (b) Negative image of Fig 1 (b)

Fig 5 (a) and (b) shows the result of low pass filtered image of Fig 1 (a) with kernel size of 31x31 and result of low pass filtered image of Fig 1 (b) with kernel size of 23x23. From the figure it is observed that the low pass filtered image provides blurred version of the input image, which means that it removes the noise, fine details and high frequency components present in the original image. The kernel sizes of the filter have more influence on the output image. If the kernel size is large, the image becomes more blurred i.e. the output image has less fine details and more amount of noise is reduced and vice versa. Low pass filtering is an intermediate stage in spatial enhancement technique.

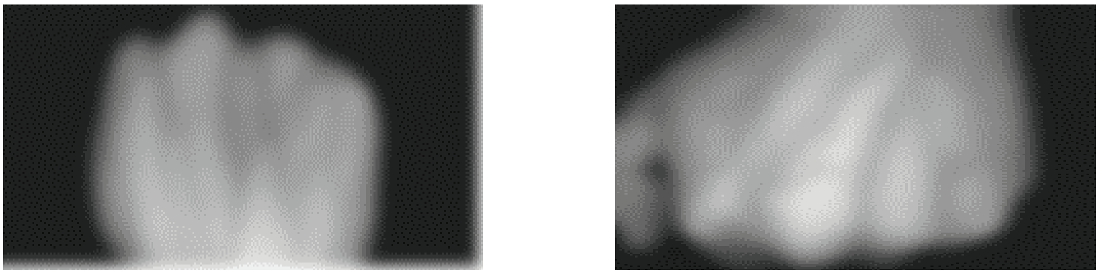

Fig 5 (a) low pass image with 31x31filter size of Fig 1 (a); 5 (b) low pass image with 23x23 filter size of Fig 1 (b)

Fig 6 (a) shows the result of high pass filtered image of Fig 1 (a) with kernel size of 31x31 and Fig 6 (b) shows the result of high pass filtered image of Fig 1 (b) with kernel size of 23x23 respectively. From the figure it is observed that high pass filtered image consists of only fine details, high frequency components and noise. High pass filter is also an intermediate stage in spatial enhancement technique.

Fig 6 (a) high pass image with 31x31filter size of Fig 1 (a); 6 (b) high pass image with 23x23 filter size of Fig 1 (b)

Fig 7 (a) shows the result from unsharp mask enhancement technique with k=0.7 of Fig 1 (a). The Fig 7 (b) shows the result of unsharp image enhancement technique with k=0.8 of Fig 1 (b). The value of k ranges from 0.2 to 0.8 but by providing in this range the unsharp image has very little enhancement and has only slight modification from the original image. By assigning k value larger, the image enhancement is more. Unsharp masking is a spatial type enhancement technique but with specified k range this technique cannot be applied. Fig 7 (c) shows the unsharp image with k=4.7 where the vein pattern are enhanced comparing to the original image Fig 1 (a). The fig 7 (d) shows the enhanced image with value of k=4 of Fig 1 (b). Fig 7 (e), (f) shows the result from laplacian sharpening enhancement technique for Fig 1 (a) and Fig 1 (b) without scaling. From the figure it is observed that veins are enhanced but without scaling.

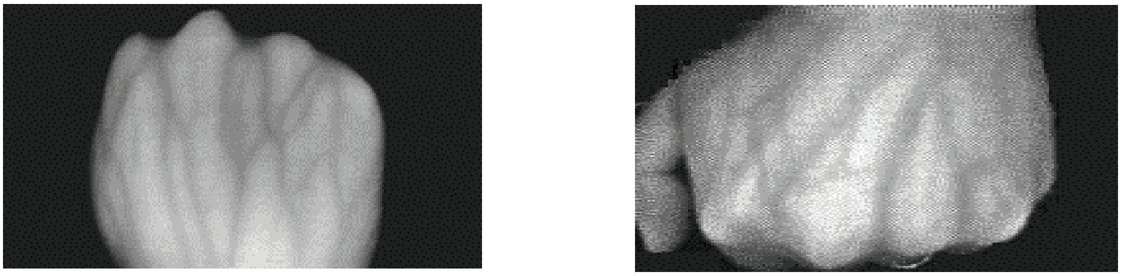

Fig 7 (a) Unsharp image with k=0.7 of Fig 1 (a); 7 (b) Unsharp image with k=0.8 of Fig 1 (b)

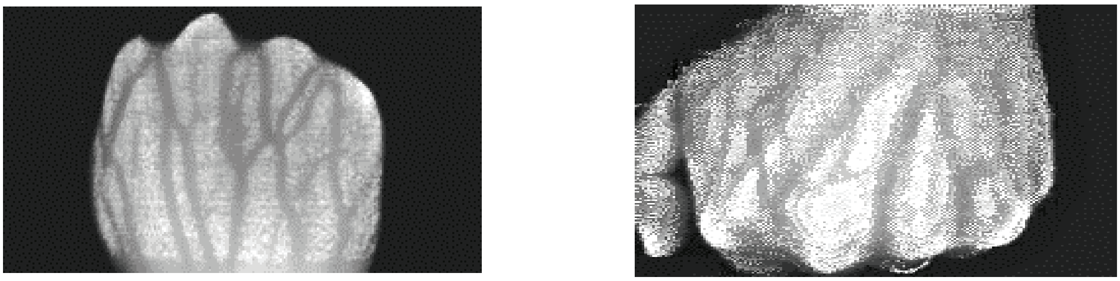

Fig 7 (c) Unsharp image with k=4.7 of Fig 1 (a); 7 (d) Unsharp image with k=4 of Fig 1 (b)

Fig 7 (e) Laplacian image of Fig 1 (a); 7 (f) Laplacian image of Fig 1 (b)

Fig 8 (a) shows the high boost filtered image with A=1.05 of the Fig 1 (a) and 8 (b) shows the high boost filtered image with A=1.15 of the Fig 1 (b), the value of A ranges greater than or equal to 1. In this the vein patterns are extracted but the contrast is very low.

Fig 8 (a) high boost filtered image with A=1.05 of Fig 1 (a); 8 b) high boost emphasis filtered image with A=1.15 of Fig 1 (b)

Fig 9 (a) and (b) shows the result from histogram equalization of high boost filtering technique for the Fig 1 (a) and Fig 1 (b) respectively. This is combinational enhancement technique which provides better result compared to all other enhancement technique. After enhancing the vein patterns, smoothing the image is necessary because histogram equalization produces undesirable effect. The smoothened image in Fig 9 (c) is threshold by adaptive method to detect the vein patterns alone as in Fig 9 (d).

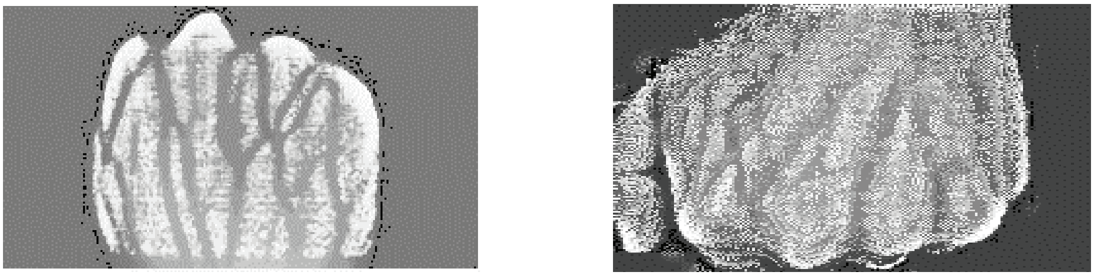

Fig 9 (a), (b) histogram equalization of high boost filtered image

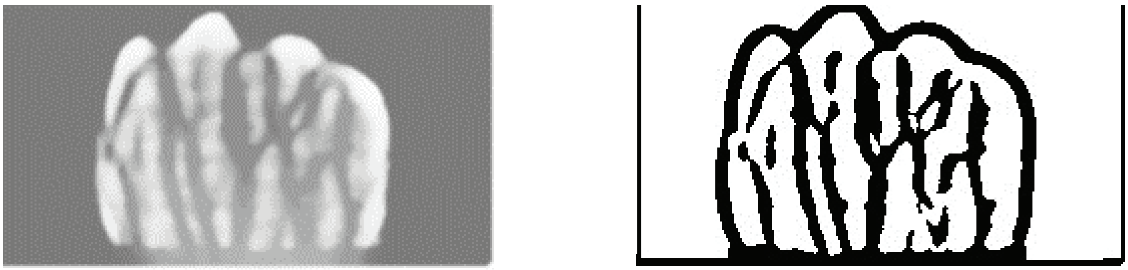

Figure9 (c) smoothened image; 9 (d) adaptive threshold image

The smoothening operation is done by using Gaussian filter and then adaptive threshold to visualize only vein pattern. This method provides better vein perception because the vein can be further easily detected by the machine. Table.1 shows the image quality measure based on full-reference method and is evaluated for the above discussed enhancement technique [9]. The quality of the enhanced image is evaluated by comparing it with a reference image that is assumed to have perfect quality. The result clearly shows that the histogram equalization of high boost filter provides better result.

Table.1 image quality measure for the enhancement technique

Method	Mean Square Error	Peak Signal to Noise Ratio	Normalized Cross Correlation	Average Difference	Structural content	Maximum Difference	Normalized Absolute Error
Negative	1.7368e+004	5.7332	0.6358	19.2455	1.5228	255	0.6207
Gray level Slicing	3.0276e+004	3.3198	0.3434	83.0386	2.7874	255	0.8435
Histogram Equalization	1.6951e+004	5.8388	0.5952	25.8667	1.7651	255	0.6637
Unsharp filter	2.5992e+004	3.9823	0.3742	78.6705	3.1098	226	0.8102
High boost filter	4.1402e+004	1.9606	0.0441	167.5173	141.0265	255	0.9640
Histogram Equalization of high boost filter	1.39838e+004	6.6748	0.6481	18.3025	1.6489	255	0.6000

4. Conclusion

The various contrast enhancement techniques are effective applied on the captured hand image using OpenCV in eclipse platform. From these techniques; histogram equalization of high boost filtered image gives the best result and hopefully could give exact information about the vein pattern in the captured image. As a result, vein can be detected using this technique appears to be clearer and would provide ease further analysis in vein applications.

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